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Experimental teaching of the subjects of the energy area of the study plan of the mechanical electrical engineering career of the FES Cuautitlan

Enseñanza experimental de las asignaturas del área de energía del plan de estudios de la carrera de ingeniería mecánica eléctrica de la FES Cuautitlán

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Abstract

This paper describes the activities that have been carried out to improve the teaching of some of the subjects in the energy area of the study plan for the Mechanical Electrical Engineer career at the Facultad de Estudios Superiores Cuautitlán. The activities carried out both by academics and by social service students and thesis students, include the preparation of notes, laboratory practice manuals and the design and construction of the experimental prototypes required in the practices. The subjects that were considered are: Heat transfer, Air conditioning and refrigeration, Alternative sources of energy, Conventional generation plants, Use of solar energy and Energy saving techniques. It should be mentioned that most of these subjects are electives of the energy module of the study plan and are considered as totally theoretical subjects, therefore, the contribution of the work is to implement experimental teaching to these subjects. At the end of the work, the experimental prototypes that were elaborated to carry out the practices of the different manuals presented are described.

Experimental teaching, Notes and manuals, Experimental prototypes

Resumen

En el presente trabajo se describen las actividades que se han realizado para mejorar la enseñanza de algunas de las asignaturas del área de energía del plan de estudios de la carrera de Ingeniero Mecánico Electricista de la Facultad de Estudios Superiores Cuautitlán. Las actividades realizadas tanto por académicos como por los alumnos de servicio social y tesistas, incluyen la elaboración de apuntes, manuales de práctica de laboratorio y el diseño y construcción de los prototipos experimentales requeridos en las prácticas. Las asignaturas que se consideraron son: Transferencia de calor, Ingeniería ecológica, Aire acondicionado y refrigeración, Fuentes alternas de energía, Plantas de generación convencional, Aprovechamiento de la energía solar y Técnicas de ahorro de energía. Cabe hacer mención que la mayoría de estas asignaturas son optativas del módulo de energía del plan de estudios y están consideradas como asignaturas totalmente teóricas, por lo cual, la contribución del trabajo es implementar la enseñanza experimental a estas asignaturas. Al final del trabajo se describen los prototipos experimentales que fueron elaborados para la realización de las prácticas de los diferentes manuales presentados.

Enseñanza experimental, Apuntes y manuales, Prototipos experimentales

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Introduction

At the Facultad de Estudios Superiores Cuautitlán we have the Mechanical and Electrical Engineering degree, whose study plan dates back to 2012. The study plan includes several terminal modules, among them is the energy module where the subjects of Air Conditioning and Refrigeration, Alternative Energy Sources, Conventional Generation Plants, Solar Energy Use and Energy Saving Techniques are included. It is worth mentioning that, although they are not included in the module, the subjects Heat Transfer and Ecological Engineering, which are in the intermediate semesters of the course, were considered.

Some academics who collaborate in the FESC's Renewable Energy Research Laboratory, seeing that most of the subjects in the terminal module are theoretical in nature, proposed to develop laboratory practices, with their respective experimental prototypes, for these subjects, with the support of students who participated as social service or as thesis students.

This proposal has been worked under the support of different institutional projects such as the Program to Support Projects for the Innovation and Improvement of Teaching (PAPIME), projects PE102015 and PE101218 and the Internal Program to Support Research Projects (PIAPI) projects 1850 and 2023.

For each of the aforementioned subjects, the respective notes and a manual of experimental practices were prepared, and experimental prototypes were adapted or designed and built to be used in the proposed practices.

Heat transfer

This subject is taught in the eighth semester of the course and its objective is for the student to be able to establish criteria to analyze the importance of heat transfer in various devices commonly used in engineering, as well as to evaluate the magnitude of the same.

The notes that were elaborated contemplate the following topics:

1. Fundamentals. Basic concepts of thermodynamics are reviewed and the importance of heat transfer and its applications are mentioned.

2. Conduction. Heat conduction through flat wall, hollow sphere and cylinder is analyzed, giving applications of each one.

3. Convection. Fundamentals of fluid mechanics are recalled and heat flow by natural or forced convection in tubes, flat surfaces, cylinders and spheres is analyzed.

4. Radiation. The basic concepts of solarimetry, thermal properties of materials and emitted and absorbed radiation are taught.

5. Heat exchangers. The classification of heat exchangers is given and the variables involved in their processes are explained.

The experimental practices designed for this subject are the following:

Practice 1.- Demonstration of zero law of thermodynamics or thermal equilibrium. It aims to demonstrate how the heat flow goes from a body with higher temperature to one with lower temperature, and the flow ceases to exist when both bodies get the same temperature.

Practice 2.- Heat conduction. The objective is that the student understands how the heat flow varies through the bodies depending on their thermal conductivity.

Practice 3.- Heat convection. The objective is that the student appreciates how heat flow can depend on the medium that transports it.

Practice 4.- Natural and forced convection. The objective is that the student identifies the difference between the two types of convection.

Practice 5.- Radiation. The objective is to visualize how heat is transferred by radiation.

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The demonstrative equipment of heat transfer is used for the realization of the practices. [1] Figure 1 shows the notes and the practice manual prepared for the heat transfer course.

Ecological engineering

This course is taught in the eighth semester and its objective is that at the end of the course the student will have sufficient knowledge to reduce and avoid pollution both in the work area and in industrial processes, applying new generation clean technologies.

Figure 1 Notes and practice manual for the subject of Heat Transfer
Source: Own elaboration

The notes that were prepared include the following topics:

1. General aspects of ecology and environmental pollution. General concepts such as ecology, ecosystem, population, trophic relationships and the different types of pollution are defined.

2. Air pollution. The types of sources of pollution, how it is avoided, the damage to the ecosystem and the existing programs for the control of polluting emissions are described.

3. Water pollution. Describes how water is contaminated and decontaminated, the damage to the ecosystem and how water is supplied to the MCMA.

4. Soil contamination. It explains how soil can be contaminated and decontaminated, what is done to control garbage and its final disposal, and the damage to the ecosystem.

5. Clean energies. A brief description is given of the alternatives available to produce thermal and electrical energy without emitting greenhouse gases.

6. Thermal pollution. The causes that generate it, how to avoid it and the damage it causes to the ecosystem are explained.

7. Noise pollution. The sources that generate it are explained, as we can control the noise and the damages that it produces to the ecosystem.

8. Radioactive contamination. The sources that emit radiation, the damage to the ecosystem and the main nuclear accidents that have occurred throughout history are explained.

The practical activities proposed are the following:

Practice 1.- Air decontamination. Its objectives are to know the ways in which air pollution can be reduced in terms of suspended particles.

Practice 2.- Water decontamination. The objective is to observe the process of water purification by means of filters.

Practice 3.- Water desalination. The objective is that the student knows an alternative for the separation of dissolved salts in water, using solar energy.

Practice 4.- Water reuse and rainwater harvesting. The objective is to design a system for the reuse of water in a house, considering the design of the water filter used in practice 2.

Practice 5.- Waste recycling. It has as objective to know the options for the reuse of some materials thrown in the waste/garbage of the houses.

Practice 6.- Soil decontamination. The objective is to learn about the different ways in which soil can be decontaminated.

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Practice 7.- Recycling of organic matter. Its objective is to observe the principle of operation of the biodigester and its application with organic matter. Due to the time required for the degradation of organic matter, it is carried out in several sessions.

Practice 8.- Energy saving - food cooking. The objective is to understand one of the applications of the greenhouse effect phenomenon caused by solar rays.

Practice 9.- Energy saving - food preservation. Its objective is to learn and know a new way of preserving food.

Practice 10.- Energy saving - food roasting. The objective is that the student learns about an alternative for roasting food using solar energy as heat supply.

In the practices, the prototypes of solar water evaporator, biodigester, oven, dryer and solar roaster are used. [2, 3 and 4] Figure 2 shows the notes and the practice manual prepared for the course.

Air conditioning and refrigeration

This is a compulsory subject of the energy terminal module and its objective is that the student will have the necessary knowledge to modify the temperature and humidity of a space in industry or housing; will understand the design of both a conventional system and a passive system; will be able to reduce the thermal load of the space to be air-conditioned through the use of thermal insulation in the building envelope and the use of solar or bioclimatic architecture.

Figure 2 Notes and manual of ecological engineering practices
Source: Own elaboration

The notes prepared include the following topics:

1. General concepts. A reminder of the laws of thermodynamics, ideal gas, properties of the vapor-air mixture and the psychrometric tables and chart is given.

2. Psychrometric processes. Psychrometric laws, two-flow mixtures, heating, cooling, humidification and dehumidification processes and their combination are mentioned.

3. Characteristics of the supplied air. Calculations are made of the amount of air required, humidity, latent and sensible heat and return air.

4. Comfort conditions. The factors that influence comfort are taught, the sensation of comfort and the factors that alter it are discussed. Diagrams used to support the calculation are presented, such as the comfort charts of ASHRAE, Olgyay and Givoni.

5. Thermal balance. The thermal load of the space to be air-conditioned is quantified, such as sensible heat gains by occupants, equipment, environment and solar radiation.

6. Conventional method to modify the temperature and humidity of the air. The systems used to heat and cool the air are shown, as well as the equipment used to humidify and dehumidify the air.

7. Air conditioning alternatives. The passive systems used for passive heating, cooling, humidification and dehumidification are described. Strategies to reduce the thermal load such as thermal insulation of the envelope and the use of solar architecture and bioclimatic design are also given.

8. Heating and cooling. The equipment used for heating and the principles of compression cooling are taught.

The practical activities proposed for this subject are:

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Construction of the Psychrometric Chart for Cuautitlán, Edo. de México. Its objective is to know the psychrometric properties of the air - water vapor mixture.

Processes of heating, cooling, humidification and dehumidification of air, using conventional methods. The objective is to know the conventional methods to modify the air temperature and humidity.

Practice 3.- Processes of heating and humidification, heating and dehumidification, cooling and humidification and cooling and dehumidification of air, using conventional methods. Its objective is to know the combinations that can be had with psychrometric processes.

Practice 4.- Processes of heating, cooling, humidification and dehumidification of air, using passive systems. The objective is to know the passive systems to modify the temperature and humidity of the air.

Practice 5.- Processes of heating and humidification, heating and dehumidification, cooling and humidification and cooling and dehumidification of air, using passive systems.

Its objective is to know the passive systems that allow modifying the temperature and relative humidity of the air.

Practice 6.- Reduction of thermal load using thermal insulators. The objective is to observe how the thermal load is reduced by using insulating materials.

Reduction of thermal load using reflective paints, solar control film and building orientation. The objective is to visualize how the thermal load can be reduced by using reflective materials.

Practice 8.- Principle of operation of a refrigeration system. The objective is that the student understands the principle of operation of a refrigeration system.

For the realization of the practices the demonstrative equipment of air conditioning and that of a refrigeration system are used. [5] Also the prototype of a passive system. [6] Figure 3 shows the notes and the practice manual prepared for the course.

Figure 3 Notes and manual of Air conditioning and refrigeration practices
Source: Own elaboration

Alternative Energy Sources

This is a compulsory subject of the energy module and its objective is to broaden your understanding of the existing means for the operation of power generation plants, complementary to thermoelectric and hydroelectric plants.

The topics included in the notes are the following:

1. Alternative energy sources. The energy panorama and the need to take advantage of alternative sources for Mexico and the world are presented.

2. Solar energy plants. The different electric power and thermoelectricity generation plants are described, explaining the characteristics of the equipment and the availability of the solar resource.

3. Geothermal energy. A brief history of its application, the different uses that can be given to the heat of the ground and a description of the geothermal plants.

4. Tidal power. A review of the history of the use of tidal energy, the four options available to obtain energy from the sea, their advantages and limitations.

5. Generation with biomass. It defines what biofuels are and their characteristics, especially biomass. The availability of the resource and the form of degradation to obtain the fuel is reviewed.

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6. Hydrogen. A brief history is given regarding the obtaining and use of hydrogen, fuel cells and its advantages and limitations.

7. Wind energy plants. A review of the history of wind energy, its availability, how to use it to generate energy and its limitations.

8. The magnetohydrodynamic generator. Its operating principle, advantages and limitations are described.

9. Other types of generation. Other alternatives such as the generator, voltaic pile, fuel cells, radioisotope thermoelectric generator and application cases are described.

The proposed practical activities are:

Practice 1, Solar heating. Its objective is to observe the principle of operation of a solar water heater.

Practical 2, Photovoltaic panel. The objective is to observe the principle of operation of a photovoltaic cell.

Practice 3, Biomass. Its objectives are to observe the principle of operation of a biodigester, to test the generation of energy using organic wastes and to determine which organic wastes produce a greater amount of biogas. This practice is carried out in three sessions.

Practice 4, Hydrogen cell. Its objective is to observe the principle of operation of a hydrogen cell.

Practice 5, Wind turbine. Its objective is to know the variables involved in the selection of the type of wind turbine.

Practice 6, Principle of operation of a refrigeration system. Its objective is to visualize the principle of operation of a refrigeration system.

The prototypes solar heater, photovoltaic panel and biodigester, the hydrogen cell kit and the didactic equipment of a refrigeration system are used in the practices.

Figure 4 shows the notes and the practice manual prepared for the course.

Conventional generation plants

This is a compulsory subject of the energy module and its objective is to identify the basic components of a conventional generation plant, such as hydroelectric, nuclear and thermoelectric plants.

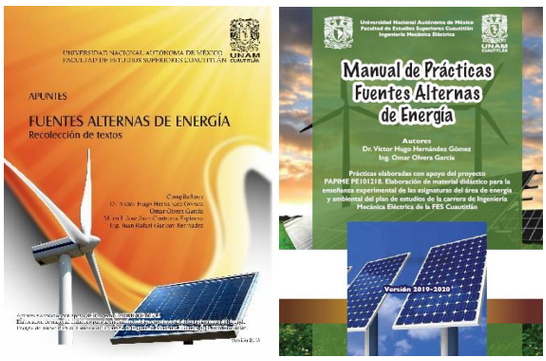

Figure 4 Notes of the Alternative Energy
Source: Own elaboration

The course notes include the following topics:

1. Energy panorama. A brief introduction is given on the sources of energy generation in Mexico and its energy resources.

2. Necessary infrastructure in any plant. The main and secondary equipment involved in the generation of electric power such as steam turbines, gas turbines, steam generators, condensers, etc. are described.

3. Hydroelectric plants. The factors by which this type of power plants can be used are described.

4. Thermoelectric plants. The thermodynamic cycle with which they operate, their main characteristics and what is required to select this type of power plant are described.

5. Nuclear energy conversion. The concepts of nuclear physics, plant safety and the different types of reactors used are briefly mentioned.

6. Fundamentals of coupling between mechanical and electrical systems. The fundamentals of electrical generators used in power plants are taught.

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The proposed activities are as follows:

1. Energy panorama. Its objective is to make the student investigate how electric energy is generated in Mexico, differentiating them according to the type of fuel used.

2. Design of a thermoelectric plant. The student will design a power plant of this type considering the resources available at FES Cuautitlan, such as space, water, etc. The student will select the type of turbine, pumps, electric generator, compressor, cooling tower, etc., to be used.

3. Design of a hydroelectric power plant. The student will design a hydroelectric power plant considering the use of the Cuautitlan River that passes near FESC. The student will design the size of the reservoir, select the type of turbine and electric generator to be used.

4. Design of a combined cycle power plant. The student will design a power plant to be located at the Facultad de Estudios Superiores Cuautitlán, considering the power cycles involved in the process and the selection of its equipment.

5. Design of a nuclear power plant. Design a nuclear power plant to be located at the Facultad de Estudios Superiores Cuautitlán, justifying the pumping system, type of nuclear reactor, steam turbine, condenser and water treatment system to be used.

Figure 5 shows the notes and the practice manual of the course.

Figure 5 Notes and practice manual of the course on Conventional Generation Plants
Source: Own elaboration

Use of solar energy

This is an elective course of the energy module and its objective is to provide the student with the fundamental knowledge for the study and application of solar energy, as well as to teach the techniques for calculating the solar resource, the different forms of its use and application.

The notes that were elaborated for this subject include the following topics:

1. Basic concepts. Concepts such as the solar constant, spectral distribution of extraterrestrial radiation, the coefficient of heat transfer by radiation, thermal properties of materials, emittance of the sky, direct and diffuse radiation, measurement tools, etc., are described.

2. Measurement of solar radiation. It includes the estimation of solar radiation, description of the apparent motion of the sun, the projection of solar radiation and the description of the solar graph.

3. Application of solar energy. Examples of the applications of solar energy in flat plate collectors, concentrators, photovoltaic panel, solar pond, distillers, solar refrigeration and solar thermal plants are presented.

4. Solar architecture. Recommendations are given on how the combination of sun, wind and building structure can contribute to thermal comfort. Options such as the orientation of the structure, microclimatic effects, envelope protection methods and passive systems are discussed.

The practical activities proposed for this subject are:

Practice 1. Construction of a sundial. In this practice the student observes the apparent trajectory of the sun, determines the cardinal axes of FES Cuautitlán and builds a sundial for FES Cuautitlán.

Practice 2. Determination of the azimuth and solar height with the solar graph. Its objectives are to understand the use of the solar diagram and to determine the solar azimuth and altitude for a given date.

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Practice 3. Solar heating. The objective is to observe the principle of operation of a solar water heater.

Practice 4. Photovoltaic panel. The objective is to observe the principle of operation of a photovoltaic cell.

Practice 5. Heat discharge system. The objective is to know the passive systems to modify the temperature and humidity of the air.

Practice 6. Solar oven. The objective is to understand one of the applications of the greenhouse effect phenomenon and to observe the cooking of food using solar energy.

Practice 7. Solar dryer. The objective is to learn and understand a new way of preserving food by removing moisture from the product that produces microorganisms, quantify the loss of moisture and observe how its appearance is modified.

Practice 8. Solar evaporator. The objective is to learn about an alternative for the separation of salts dissolved in water, using solar energy and for the student to observe the characteristics of the water obtained.

In the practices, the prototypes of solar heater, photovoltaic panel, passive system, solar oven, solar dryer and solar water evaporator are used. Figure 6 shows the notes and the practice manual prepared for the course.

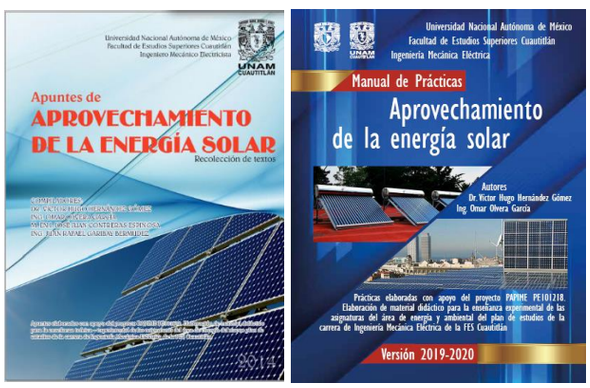

Figure 6.- Notes and practice manual of the course on Solar Energy Use. Own source.

Energy saving techniques

This is an elective course of the energy module that provides the student with sufficient tools to apply energy saving programs in any type of industrial, commercial and residential activity.

The notes include the following topics:

1. Introduction. It describes the concept of energy saving, its benefits, the feasibility in the application of energy saving programs and some energy efficiency standards are presented.

2. Lighting. The use of the sun to improve the amount of light in spaces, the characteristics and application of energy saving lamps and the application of color theories in surfaces are described.

3. Air conditioning and refrigeration. The applications of thermal insulation, passive systems Trombe wall, wall/ceiling shield, heat discharge systems are defined and sustainable architecture is explained.

4. Thermal energy generation. Alternatives to generate thermal energy such as solar heaters, accumulators, etc. are presented.

5. Generation of electrical energy. Some alternatives for the generation of electric energy are presented, such as the use of solar (photovoltaic panels), wind (wind turbines) and sea (tidal) energy, as well as the application of hydrogen, fuel cells, biogas, thermoelectricity and their applications.

The practical activities proposed are:

Practice 1. Energy efficiency standards. Its objectives are to apply energy efficiency standards, to know briefly the methodology for the calculation and selection of an air conditioning system and to know and apply the NOM-020-ENER-2011 standard.

Practice 2. Energy saving in lighting. The objective is to observe that the same amount of lighting can be obtained with less energy consumption.

Practice 3. Energy saving in air conditioning systems. The objective is to know the passive systems to modify the temperature and humidity of the air and to observe the energy savings that can be obtained by using these passive systems in air conditioning.

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Practical 4. Energy saving by reducing the thermal load in air conditioning systems, using thermal insulators. Its objectives are to observe how energy can be saved in air conditioning systems by using insulating materials in the building envelope and to observe the heat flow through different materials.

Practice 5. Alternative energy generation. Solar heating. Its objectives are to observe the energy savings that can be achieved with a solar water heater and to understand the principle of operation of a solar water heater.

Practice 6. Alternative energy generation. Photovoltaic panel. Its objectives are to observe how electrical energy can be generated with solar energy and to learn the principle of operation of a photovoltaic cell.

Practice 7. Alternative energy generation. Wind turbine. Its objectives are that the student observes the use of the wind turbine to generate electricity and learn the variables involved in the selection of the type of wind turbine.

Practice 8. Alternative energy generation. Biomass. Its objectives are to observe the principle of operation of the biodigester, to verify the generation of energy using organic waste and to determine which organic waste produces a greater amount of biogas.

Practice 9. Alternative energy generation. Hydrogen cell. The objectives of this practice are to observe the generation of electricity by means of a hydrogen cell and to know its operating principle.

In the practices, the prototypes of passive system, solar heater, photovoltaic panel and biodigester, the heat transfer demonstration equipment and the hydrogen cell kit are used. Figure 7 shows the notes and the practice manual prepared for the course.

Figure 7 Notes and practice manual of the energy saving techniques course
Source: Own elaboration

Prototypes and equipment used in the practice manuals

Heat transfer demonstration equipment. It is designed to generate a heat flow that is passed through different materials, with the purpose of being able to quantify the conduction properties of the material. Figure 8 shows the equipment.

Figure 8 Heat transfer demonstration unit
Source: Own elaboration

Solar water evaporator. This is used to separate dissolved solids from water by evaporation, using solar energy as fuel. The water is placed in a container, which is covered with glass to allow the sun's rays to enter, capture them and form a greenhouse effect inside. Figure 9 shows the prototype.

Figure 9 Solar evaporator prototype
Source: Own elaboration

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Biodigester. There are 12 batch-type biodigesters, which allow taking readings of the biogas generated, as well as the pH of the substrate. The biodigesters are filled with different organic materials and allow monitoring the amount of methane formed during the retention time. Figure 10 shows the biodigesters constructed.

Figure 10 Biodigester prototype
Source: Own elaboration

Solar oven. These prototypes allow observing the cooking of food using solar energy as fuel. It is an insulated box which allows the sun's rays to enter through its cover, which is a glass, increasing the internal temperature of the oven by means of the greenhouse effect. The oven is shown in Figure 11.

Solar dryer or dehydrator. This prototype allows the removal of moisture from food products. The product to be dried, preferably in slices or strips, is placed on the trays and the container is closed. Air, which was heated in a solar energy panel, is passed over the product and removes its moisture. The moist air is let out through the top of the solar dryer. This equipment is shown in Figure 12.

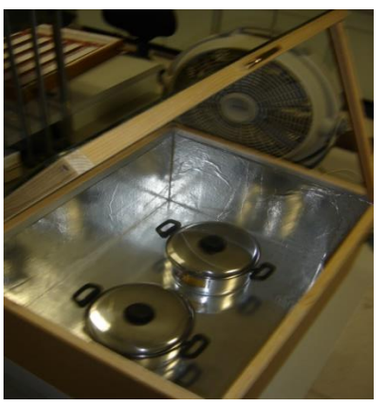

Figure 11 Solar oven prototype
Source: Own elaboration

Figure 12 Solar dryer or dehydrator
Source: Own elaboration

Solar roaster. The prototype allows roasting food using solar energy as fuel. Steaks, chicken and hot cakes have been grilled. Figure 13 shows the solar grill prototype.

Figure 13 Solar grill prototype
Source: Own elaboration

Air conditioning demonstration equipment. It is a prototype that allows studying the processes of heating, cooling, humidification and dehumidification, as well as combinations among them. The equipment was designed with the necessary instrumentation to observe and measure the changes that the air undergoes in each process, that is, 3 interchangeable modules were created for the study of each psychrometric process and its possible combinations. The equipment is shown in Figure 14.

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Figure 14 Air conditioning demonstration unit
Source: Own elaboration

Passive system. These prototypes work under the principle of the Trombe wall and the wall heat discharge system. The first one measures one square meter of surface and has a set of electrical resistances to be used inside the laboratory. The second equipment has a height of 2 meters by 50 centimeters wide, although it has electrical resistors, it is used to expose it to the sun's rays. In this equipment, trays with water can be placed for the heating, cooling and humidification process; or desiccant material can be placed for the dehumidification process. Figure 15 shows the first prototype manufactured.

Figure 15 Prototype of passive system for laboratory
Source: Own elaboration

Didactic equipment for a refrigeration system.

This equipment makes it possible to simulate and observe the operation of the basic refrigeration cycle, which has the appropriate instrumentation so that students can take readings, create tables, perform calculations, develop their own practices and generate conclusions. A box with acrylic walls and a metal structure was built in order to observe the operation of the equipment that make up the refrigeration system, such as the condenser, evaporator, valves and compressor.

Sight glasses, thermometers and pressure gauges were installed at different points of the system to visualize the status, temperature and pressure of the refrigerant used. Figure 16 shows the equipment.

Figure 16 Didactic equipment of a refrigeration system
Source: Own elaboration

Solar heater. The prototype consists of three sections connected in series to a water heater. The translucent surface is made of acrylic and a sheet frame. It has a mechanism to modify its inclination, to operate it at any time and season of the year. The heater and water heater have thermocouples in different parts of the system in order to record the water temperature. Figure 17 shows the solar heating system of the laboratory.

Figure 17 Solar water heating prototype
Source: Own elaboration

Photovoltaic panel. The system consists of two photovoltaic panels, inverter and gel battery. Figure 18 shows the photovoltaic panel of the laboratory.

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Figure 18 Laboratory photovoltaic panel
Source: Own elaboration

Hydrogen cell kit. The kit consists of three parts: electrolysis, fuel cell and generator, and is powered by solar energy. Figure 19 shows the diagram of the equipment.

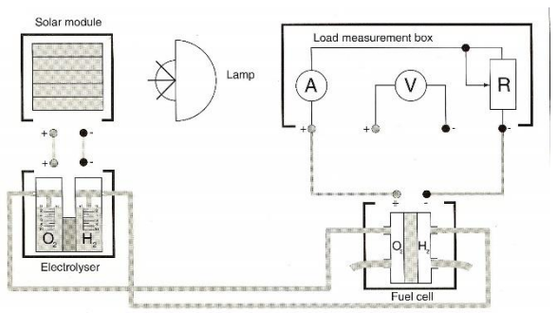

Figure 19 Hydrogen cell kit
Source: Own elaboration

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Conclusions

With the support of the notes and the practice manuals, it has been possible to improve the teaching of the subjects in the energy area covered in this document.

It is worth mentioning that during this pandemic, some of the notes have been used as a textbook in virtual environments such as Classroom and practical activities have been selected that can be performed at home without the need for experimental prototypes. When the traffic light is changed and the activities are resumed at FESC, both the notes and the practice manuals will serve for the mixed modality.

References

1. Juan Carlos Espinal Arellano, Omar Olvera García, Víctor Hugo Hernández Gómez. Diseño de un prototipo experimental para la enseñanza de los mecanismos de transferencia de calor. Memorias del Congreso Científico Tecnológico de las carreras de Ingeniería Mecánica Eléctrica, Industrial y Telecomunicaciones, sistemas y electrónica, AÑO 1. No. 1. SEPTIEMBRE 2016 – AGOSTO 2017. ISSN-2448-7236.

2. Víctor Hugo Hernández Gómez, Omar Olvera García y David Morillón Gálvez. Prototipo para separar sólidos del agua mediante la evaporación solar. Revista de Prototipos Tecnológicos. 2016, 2-5: 27-42. ISSN: 2444-4995. España.

3. Víctor Hugo Hernández Gómez, Omar Olvera García, Jesús González Aguirre, Luis González Maya. Estudio del potencial de generación de metano empleando diferentes materias orgánicas de desecho. Tercer Congreso Interdisciplinario de Energías Renovables, Mantenimiento Industrial, Mecatrónica e Informática. Querétaro. 25 al 26 de octubre del 2018.

4. Hernández Gómez Víctor, Olvera García Omar, Guzmán Tinajero Pedro, Morillón Gálvez David. Secado de frutas y verduras con energía solar. Revista de Sistemas Experimentales. 2017, 4-11: 22-33. ISSN: 2410-3950. Bolivia.

ISSN 2410-3977

5. Iveth Sánchez Barrera, Yarabi de la Rosa Flores, Alan Castañeda Monroy, Omar Olvera García, Víctor Hugo Hernández Gómez. Diseño, construcción y caracterización de un prototipo experimental para la enseñanza del funcionamiento de un sistema de aire acondicionado. Memorias del Congreso Científico Tecnológico de las carreras de Ingeniería Mecánica Eléctrica, Industrial y Telecomunicaciones, sistemas y electrónica, AÑO 2. No. 2. SEPTIEMBRE 2017 – AGOSTO 2018. ISSN-2448-7236.

6. Víctor Hernández, David Morillón, Roberto Best, José Fernández, Rafael Almanza, Norberto Chargoy. Experimental and numerical model of a wall like solar heat discharge passive system. Applied Thermal Engineering, Vol. 26, Numbers 17-18, pp. 2464-2469, December 2006, ISSN 1359-4311. DOI: 10.1016/ j.applthermaleng.2006.01.027

ISSN 2410-3977